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ABSTRACT

Information for preparing technical reports is presented in this guide. This information includes: (1) descriptions of a technical report, an abstract, and a technical paper; (2) guidelines for writing abstracts and technical reports; (3) guidelines for developing an outline; (4) a sample student report format; and (5) a technical report appearing in a professional journal and the journal editor's instructions. The guide is designed for use as a supplement to written texts used in regular school English classes. (JN)

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REPORT WRITING STYLE GUIDE

GUIDE FOR THE PREPARATION OF REPORTS ON SCIENCE STUDENT RESEARCH PROJECTS

Prepared for
The Ohio Academy of Science

By Dolores M. Landreman
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Battelle Memorial Institute
Columbus Laboratories

SE044777

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ACKNOWLEDGMENTS

While it is common for professional men and women to help the youth of America aspire to careers in technical fields, few professionals are really pioneers. Few, for example, can bridge the gap between industry and academia, but the author of this publication, Ms. Dolores Landreman, has succeeded. We sincerely appreciate the pioneering efforts of Ms. Landreman to assist students in understanding the central role of technical communications in the advancement of science, engineering and technology. From her perspective as a former classroom English teacher and as a communcations specialist at Battelle-Columbus Laboratories, she has been able to draw upon a considerable amount of experience in compiling this guide. Let us hope that pioneers like Ms. Landreman will continue to have thousands of followers.

I also want to express my appreciation to Mr. Thomas Higgins, Manager of Marketing Services, Battelle-Columbus Laboratories, for his review of this guide during its preparation.

No project of this nature would be possible without the support of generous sponsors. We especially appreciate the financial support from The Standard Oil Company of Ohio which defrayed initial publication costs. While preparing this report many corporations and technical societies were contacted for suggestions and examples. We acknowledge here those who responded to our requests:

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Lynn Edward Elfner
Executive Officer
The Ohio Academy of Science
August 1984

TO STUDENTS AND TEACHERS

"It is impossible to dissociate language from science or science from language, because every natural science always involves three things: the sequence of phenomena on which the science is based; the abstract concepts which call these phenomena to mind; and the words in which the concepts are expressed. To call forth a concept a word is needed; to portray a phenomenon, a concept is needed. All three mirror one and the same reality."

From
Antoine Laurent Lavoisier,
Traite Elementaire de Chimie.

The Ohio Academy of Science, in providing this guide and in encouraging students to use it, wants to highlight the fact that much more than laboratory experiments and field observations is involved in scientific research. An appropriate research approach must be planned and followed, resources must be efficiently managed, schedules must be established and met, and accurate records must be maintained.

However, even if all this is done conscientiously and competently, the research will be pointless if the results -- the successes and failures alike -- are not effectively communicated. The results of research cannot provide benefits to anyone unless the researcher's recommendations are implemented or unless the data and insights developed are used as springboards for further investigations.

Businesses and industrial firms -- as well as governmental agencies and private research organizations -- have great interest in effective communications. The cost of poor communications can be very high: unnecessary expenditures, serious delays, avoidable accidents, lost opportunities. Many years ago the cost of poor writing was stressed by General Curtis LeMay in his foreword to the Guide for Air Force Writing:

"One of the greatest needs facing the Air Force today is to improve the quality of our writing. It takes us too long to get our ideas down on paper. We use too many words to say what we mean, and too often our meaning is not clear. Then because of poor writing, our readers have to waste their time trying to understand us."

Because effective communication is critical for the advancement of science and engineering, many employers of scientists and engineers hire professional writers and editors to help meet the challenge of communication. Many employers also

provide special writing classes; some publish their own writing manuals.

The sample student report format provided in Appendix A of this guide is intended only as a general pattern. The design of any specific report must be based on the nature of the subject matter, the intended use of the report, and the technical backgrounds and specific needs of the target audience.

Moreover, this guide is not intended as a substitute for writing texts used in regular school English classes -- only as a supplement to them. Students are urged to take advantage of all of the many opportunities presented in their English classes for improvement of their communication skills: reading, writing, speaking, and listening. One of the best ways to improve writing skills is to read widely and to analyze the techniques of the most successful authors -- from Shakespeare and the Romantic Poets to modern novelists and scientists who publish in the leading technical journals.

This guide for the preparation of reports is organized into eight major parts:

1. What is a Technical Report?
2. What is an Abstract?
3. What is a Technical Paper?
4. Writing Abstracts
5. Writing Technical Reports
6. Developing an Outline
7. Example Student Report Format
8. Example Technical Paper and Journal Editor's Instructions.

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MONTAGE OF COVERS FROM VARIOUS TECHNICAL WRITING STYLE GUIDES

8

WHAT IS A TECHNICAL REPORT?

The technical report is probably the single most important type of technical communication. In a large organization, accurate, easy-to-use reports, submitted on time, can be the best avenue for a researcher to obtain favorable recognition by management for a job well done.

Reports have a number of generally accepted functions. One specific report might have only one function, or it might have many. The major functions of reports are:

(1) to inform
(2) to stimulate to action
(3) to provide a base for planning
(4) to record.

For the preparation of an effective technical report, it is essential that you know who will use it and how it will be used. Reports often have an immediate, or direct, audience and a secondary, or indirect, audience. It is necessary to consider the nature and needs of both audiences.

In contrast to a technical paper published in the open literature, which highlights a specific scientific or engineering achievement, a technical report is a detailed description of a project. Several scientific papers, intended for various audiences or journals, may be developed from a single project. A technical report contains project management information and provides a thorough discussion of the entire project and its technical and other implications.

Reports can have various legal aspects related to their recording function. For example, a report might be important for supporting a patent application or for proving there was no negligence leading to an accident.

A report may be eagerly awaited by impatient readers -- or it may have to compete with many other reports for attention. In any case, the intended audience is usually much like the audience for which journalists write their news reports: it is busy and wants information presented as quickly and efficiently as possible. Therefore the "inverted pyramid" structure of organization used so effectively by journalists -- with the "Five W's" revealed immediately -- is, generally speaking, the best structure for technical reports also. The "Five W's" are:

Who?
What?
Why?
When?
Where?
(and sometimes How?)

Decision makers who read reports ordinarily want the following information given as soon as feasible:

1. Who wrote this report?
2. What authority is represented?
3. What is the background?
4. Why was the report written?
5. Where was the work done?
6. When?
7. By whom?
8. What were the results of the work?
9. What decisions am I being asked to make?
10. What will the benefits be if I follow recommendations?
11. When will the benefits be available?
12. What costs are involved - time? money? safety? other?
13. What might be the impacts on related or other planned activities?
14. How reliable is this information (procedures followed? quality control?)
15. What were the problems encountered? What are the implications?

If such information is given early in the report, the reader can make the needed decisions quickly -- or refer the report immediately to a more qualified decision maker. There are many devices for making the decision maker's job easier. For example:

1. A Title Page with meaningful title, date, author, etc.
2. A clear and accurate Abstract of the report
3. Clear illustrations and tables, complementing but not duplicating the text
4. Meaningful headings and subheadings for sections and subsections
5. Key sentences at beginnings of paragraphs
6. Concise, clear, concrete ("picture making") language
7. Details separated from the main text and put into appendices
8. Neatness and variety in the appearance of pages -- pleasing balance of paragraphs, lists, illustrations, "white space."

Much of the information needed by decision makers should be contained in the report title. It is important that the title be both accurate and stimulating for another reason: "retrievability." A report can easily get lost in the files (especially in a computer-controlled file) if words in the title are not selected with retrieval in mind.

Since most technical reports are based ultimately on a written proposal, or research plan, a copy of that proposal or research plan should be available for reference during the report preparation. The report must reflect the commitments made in the proposal. Any deviations must be explained and justified. This does not mean that there may not be any deviations. The nature

of research is such that on occasion deviations from a plan or schedule are absolutely necessary.

Decision makers will be better disposed to follow the report recommendations -- to make the "right" decision -- if the report is easy to read and interesting. An important part of technical report writing -- often ignored by students and even professionals -- is careful editing and polishing.

WHAT IS AN ABSTRACT?

The rapid growth of science and technology makes it impossible for busy scientists and engineers to read, in their entirety, all of the significant literature in their particular areas of specialty. Much less are they able to read significant publications in related, or potentially related, fields. Therefore, abstracts of reports, journal articles, papers presented at conferences, and similar technical communications have become important tools for the dissemination of scientific and technical information.

Professional societies generally publish, in advance of their major conferences, abstracts of papers to be presented. This enables attendees to select sessions most pertinent to their interests. Many technical journal editors require that abstracts accompany all papers submitted for publication. A number of abstracting services distribute collections of abstracts to their subscribers. One of the best known is Chemical Abstracts Service, located in Columbus, Ohio.

WHAT IS A TECHNICAL PAPER?

A technical paper is a special kind of report that is prepared for broad distribution as part of the professional literature in a specific scientific or engineering field. It may be published in a professional journal, in a trade magazine, or in the conference proceedings of a professional society.

Usually a technical paper is based in whole or in part on a report or group of reports prepared for an industrial organization, a grant-awarding foundation, or a government agency. It does not contain information that is considered sensitive from an industrial proprietary standpoint or that has been designated as "classified" by a government agency.

The style of the technical paper usually reflects the style of comparable papers in the same field. Sometimes convention dictates, for example, the use of specific abbreviations or symbols or the types of photographs or other illustrative materials included. Editors of most professional journals provide instructions to prospective authors of papers for their publications.

Appendix B presents a representative technical paper published in The Ohio Journal of Science, the official journal of The Ohio Academy of Science. Note the abstract included and the method of making acknowledgments and of citing the literature. Appendix B also includes a reprint of the instructions for preparation of manuscripts for publication in the Journal.

WRITING ABSTRACTS

The writing of brief, informative abstracts is a special skill that should be developed by students. Here are a few suggestions for preparing abstracts listed by Edward T. Cremmins in his book, The Art of Abstracting (Cremmins, 1982):

1. Prepare an abstract that access services can reproduce with little or no change, copyright permitting.

2. State the purpose, methods, results, and conclusions presented in the original document, either in that order or with initial emphasis on results and conclusions.

3. Make the abstract as informative as the nature of the document will permit, so that readers may decide, quickly and accurately, whether they need to read the entire document.

4. Unless otherwise instructed, use fewer than 250 words for most papers and portions of monographs and fewer than 100 words for notes and short communications. For long reports and theses, do not exceed 500 words.

5. Avoid including background information or citing the work of others in the abstract, unless the study is a replication or evaluation of their work.

6. Do not include information in the abstract that is not contained in the textual material being abstracted.

7. Verify that all quantitative or qualitative information used in the abstract agrees with the information contained in the full text of the document.

8. Use standard English and precise technical terms, and follow conventional grammar and punctuation rules.

9. Give expanded versions of lesser known abbreviations and acronyms, and verbalize symbols that may be unfamiliar to readers of the abstract.

10. Omit needless words, phrases, and sentences.

The Ohio Academy of Science routinely requires abstracts from all members who wish to present papers during the annual meetings

of the Academy. The instructions reprinted below are included each year in the "Call for Papers."

> An abstract should be prepared for each paper to be presented at the annual meeting. The abstract should be a concise summary of the contents of the paper and not merely a general description of what the paper is about. Tell what the specific facts are, not what they are going to be when you talk. All important facts should be stated with brevity, but not such sparing use of words as to leave ambiguity. Abstracts should be 250 words or fewer. Tables and graphs should not be included. New techniques or new apparatus and their functions should be mentioned. New constants, critical data or formulae should be included. Names of new species should not be listed in the abstract. All organisms, chemicals, etc., should be designated by full scientific names. The value of abstracts is real and considerable, not only for those in attendance, but also for others unable to attend. Acceptable abstracts are published in the April program abstracts issue of The Ohio Journal of Science.

WRITING TECHNICAL REPORTS

A written report must be submitted for each project supported by a grant from The Ohio Academy of Science. A report is also required for projects entered in Local, District and State Science Days. This report should contain all of the elements typically found in reports prepared by researchers in industrial organizations and government agencies. It should discuss, in adequate detail for evaluation, the background of the project, the work done, the results obtained, and the conclusions and recommendations based on the results.

References used should be cited and assistance received should be acknowledged. Experimental data, statistics, notes, and computations recorded in the project log or notebook should be summarized as appropriate.

The report should be organized in generally accepted technical report format. It should be carefully checked for correctness of sentence structure, word usage, spelling, and punctuation. If possible, it should contain photographs, sketches, graphs, or other illustrations -- but only if these can contribute to effective presentation of ideas or facts. References must be cited in a consistent style. Quotations should be used only sparingly, and they must be exact.

The report should be submitted as an attachment to a Transmittal Letter (see Appendix A). It should include a Title Page, Table of Contents, and Abstract.

The example of a suitable format for student reports presented in Appendix A is provided only for general guidance.

There are many acceptable ways of organizing technical reports. Later you may find that your employer requires you to follow a specific report pattern. If so, follow the prescribed format exactly if at all possible.

In general, a typical report would contain the following major sections:

INTRODUCTION

The Introduction should prepare the reader for proper understanding of the report. It should briefly cover, for example:

- the problem or idea that stimulated the research
- the historical background of the problem or idea
- the hypothesis on which the work was based
- the scope of the study and of the report.

RESULTS, CONCLUSIONS, RECOMMENDATIONS

This can be a single section of the report, or it can be divided into two or three parts. In any event, the conclusions must be drawn from the results and the recommendations must be based on the conclusions.

TECHNICAL DISCUSSION

This section should cover all project activities and findings. Typically it provides information concerning:

- the rationale for the specific investigative approach selected
- the procedures followed
- the equipment used or the samples considered
- the results obtained and the method of analyzing them
- the implications of the results of the work.

MANAGEMENT DISCUSSION

This section should cover all management aspects of the project. For example, discuss adherence to agreed-upon budget and schedule. Any deviation or variance from the management plan presented earlier in the proposal must be explained and justified, and the implications discussed.

ACKNOWLEDGMENTS

REFERENCES

APPENDICES

Appendices might include, for example, a list of symbols or a glossary, supporting tables of detailed data, supplementary graphs, background calculations, computer printouts.

DEVELOPING AN OUTLINE

The critical first step in the preparation of a technical report is the development of a good outline. The following suggestions should help you to avoid some of the problems often associated with outlining:

(1) Summarize the message you want to convey in one sentence (the "thesis" sentence). If you can't do this, your thinking is not in focus. More analysis of the project activities and results is necessary. When you're satisfied that the sentence accurately reflects what you want to say, write it at the top of your outline page as a "target" for your report design.

(2) Use only one large sheet of paper to make your outline. Don't "fragment" your outline (and your thinking) over several sheets in a tablet. Keep the entire outline in view as you develop it so that you can see at a glance any repetitions, omissions, conflicts, imbalances, etc. The single large sheet will help you to maintain control.

(3) Decide on all major headings and subheadings before you detail the outline. Also, make decisions concerning appendix material and the placement of illustrations and tables before you detail the outline. You can then add detail in any order you want.

The sample outline on the next page is greatly simplified, but it is based on a real technical report. Note the decimal numbering system used to indicate sections and subsections. You might want to use a similar system in the outline -- and in the report itself.

Message: The pump we designed during the first-year program has great potential for giving reliable service in developing nations, and we recommend a second-year program to improve it.

1.0 Introduction
- (a) Program background
- (b) Program success
- (c) Organization of the report

2.0 Conclusions and Recommendations
- (a) Future development work should be approved
  - (1) To improve design of the cup, valves, and cylinders
  - (2) To identify or make more durable cup materials
- (b) Possibilities for production in U.S. and in developing nations should be explored

3.0 Pump Design
- 3.1 Overall Design (Figure 1 - photograph) (Figure 2 - drawing)
- 3.2 Hydraulic Design (Figure 3 - drawing)
- 3.3 Mechanical Design (Figure 4 - drawing)
- 3.4 Other Design Possibilities

4.0 Pump Operation
- introductory paragraph - pumping capacity with different design options (Table 1 - Reference Appendix A)
- 4.1 Laboratory Test Results
  - 4.1.1 With Leather Cup
  - 4.1.2 With Plastic Cup
- 4.2 Field Test Results
  - 4.2.1 With Leather Cup
  - 4.2.2 With Plastic Cup
- 4.3 Pump Safety
  - 4.3.1 Adults Operating
  - 4.3.2 Children Playing

5.0 Present Design Limitations
- 5.1 Manufacturing Problems
- 5.2 Reliability Problems
  - 5.2.1 Handle Breakage
  - 5.2.2 Cylinder Cracking

6.0 Production Requirements
- 6.1 In U.S. (Reference Appendix B)
- 6.2 In Developing Nations
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  - 6.2.3 Raw Materials Needed

7.0 Future Research Requirements
- 7.1 Design
- 7.2 Materials
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8.0 Project Management

Appendixes
- A - Details of Pump Operation
- B - List of Companies who Have Agreed To Manufacture the New Pump

SAMPLE OUTLINE

Appendix A

EXAMPLE STUDENT REPORT FORMAT

EXAMPLE TRANSMITTAL LETTER FORMAT

(USE SCHOOL LETTERHEAD STATIONERY)

May 19, 19xx

The Ohio Academy of Science
Attn: Chairman, Student Research Grants Committee
445 King Avenue
Columbus, Ohio 43201

Gentlemen:

Final Report on Student Grant Project

Project Title:
TITLE REFLECTING THE PURPOSE
AND RESULTS OF YOUR
INVESTIGATION

Attached are two copies of my report on the study I conducted under a grant from The Ohio Academy of Science. My research supervisor was Mr. John Mauderly. My English advisor was Miss Denise Dagot. The total of the grant was $185.00, and I used the entire amount.

I appreciate very much the opportunity that the grant from the Academy provided to investigate a problem of concern to me. I plan to encourage other students to submit proposals to the Academy because of the valuable practical experience they can obtain in conducting research projects and in meeting the challenge of effective technical communications.

I plan to submit a copy of my report and to prepare a display of my project results for our annual Student Science Day in Central City.

Very truly yours,

George M. Smithman

Attachment: Report (2 copies)
Under separate cover: Three experimental samples

Appendix A

EXAMPLE STUDENT REPORT FORMAT

TITLE REFLECTING THE PURPOSE AND RESULTS OF
YOUR INVESTIGATION

to

The Ohio Academy of Science

by

George M. Smithman
4455 Kendall Avenue
Central City, Ohio 43xxx

May 10, 19xx

Research Supervisor: Mr. John Mauderly
English Advisor: Miss Denise Dagot

Central City High School
462 Main Street
Central City, Ohio 43xxx

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B - Descriptive Title.....B-1

ABSTRACT

An abstract should be prepared for each student report. It should be on a separate sheet of paper, immediately after the Table of Contents. The abstract should be a concise summary of the contents of the report, not merely a general description of what the report is about. Abstracts should not exceed 250 words. All important facts and their implications should be stated with briefly, but words should not be used so sparingly as to leave ambiguity. Tables and graphs should not be included. New techniques or new apparatus and their functions should be mentioned. New constants and critical data or formulae should be included. Names of new species should not be listed. All organisms, chemicals, etc., should be designated by full scientific names.

FINAL REPORT

on

TITLE REFLECTING THE PURPOSE AND

RESULTS OF YOUR INVESTIGATION

INTRODUCTION

Your introduction should give the intended readers the necessary background for understanding your report. It should capture their interest and motivate them to read on by revealing the benefits to be derived from the reading. Benefits might include, for example, obtaining useful facts or valuable insights concerning the implications of a theory. In general, the introduction should provide the following information:

(1) Why the report was written

(2) The problem or question addressed and its significance

(3) The objective and scope of the investigation

(4) Whether the purpose was achieved and if not, why not.

These four items must not be considered mandatory. Every report is unique in many respects, and the introduction, as well as every other section, must reflect both the nature of the subject covered and the needs of the readers.

Your report might begin, for example with a sentence something like this:

> This report presents the results of a survey made in an Ohio Academy of Science student grant project. The objective was to determine the neighborhood distribution and crop types of vegetable gardens in Central City, Ohio, during the summer of 19xx.

Although your introduction should provide adequate backgound for an understanding of the rest of your report, it should be as brief as possible. Giving too much detail can make other parts of the report redundant; consequently, the report will be longer than necessary, and it will probably seem dull to the reader.

If your report must be long, you might give a brief overview of its organization in the introduction. However, do not simply repeat the Table of Contents; explain why the report is organized as it is.

It is important for you to remember that this example report format is intended only to provide general suggestions as to how your report might be organized. The nature of your project might require a quite different pattern. Consider your audiences and your purpose in writing the report.

RESULTS AND CONCLUSIONS

Describe the results of your investigation and tell what general conclusions you reached concerning them. You must conscientiously report failures as well as successes and explain the failures if you can. For example, you might have learned that sloughing of particles from the plastic container you used for samples in your experiments contaminated the samples. Therefore, your conclusion could be that your measurements of culture growth might be questionable and that you should have used some other type of container.

This section should also be adequate for understanding, but

as short as possible. Supporting details should be given later in your assessment of the project results.

RECOMMENDATIONS

State your recommendations as clearly as possible, keeping in mind the needs of the decision makers. If you make several recommendations, try to state them unambiguously and in some logical order.

If possible, word your recommendations so that yes/no ("go/no-go") decisions can be made. If recommendations are interconnected, point out the relationships. If appropriate, discuss the consequences of following or not following your recommendations.

If you separate and number your recommendations, this will facilitate discussion of them among readers of your report. For example, some members of a management review committee might express agreement with your points (1) and (3) but disagreement with your point (2).

Numbering items in a list can give the impression that some indication of priority or sequence is intended. If you want to avoid such an implication, you might choose not to number the points or to use something neutral, such as dots (bullets).

If you decide, for example, that other students should be encouraged to conduct similar experiments because your samples were contaminated, your list of recommendations might look something like this:

(1) Encourage other students to conduct similar experiments

(2) Provide a copy of this report to any students who elect to conduct such experiments

(3) Require that as the first step in their research, they investigate the effects of using specific container types.

Again, although this section should be adequate to express your recommendations (which must be based on your results and conclusions), it should be as brief as possible. Details needed by decision makers should be given later.

TECHNICAL DISCUSSION

This will probably be the longest section of your report. Its organization should reflect both the nature of your investigation and your assessment of the best way to organize the information and to present it in text, tables, and illustrations.

This section could be divided into several subsections, some of which might be subdivided as illustrated later in Project Procedures. Subsection titles and figure and table captions should be specific.

Background of the Project

You might describe the problem or question you addressed in your project in more detail than you did in the introduction and tell what stimulated your interest in finding a solution or an answer. You might tell what others have done and cite literature in the field. Include references in a special

reference section at the end of the report as illustrated in this example (1-17).

Project Approach

In this subsection, describe your general project design and the rationale behind it. For example, you might tell what assumptions you made and the implications. You might tell on what basis you selected your samples and whether you used controls and why or why not. You might tell how you decided upon the scope (for example, 1975 through 1980 and only publications of the American Chemical Society). If you conducted a personal survey, you might justify your selection of the survey population.

Project Resources

If your project involved the assembly or construction of experimental apparatus, you would describe it in this subsection. Then, provide one or more illustrations. Figure 1 shows how a sketch might be presented. Note that the word "sketch" does not appear in the caption because it is obvious that this is a sketch. On the other hand, if there might be some question, for example, as to whether an illustration is a photograph or an artist's rendition, the caption should make clear what it is. It might be necessary to include in a photograph some familiar object, such as a ruler or a coin, to indicate relative size, or you might need to state dimensions or comment on color.

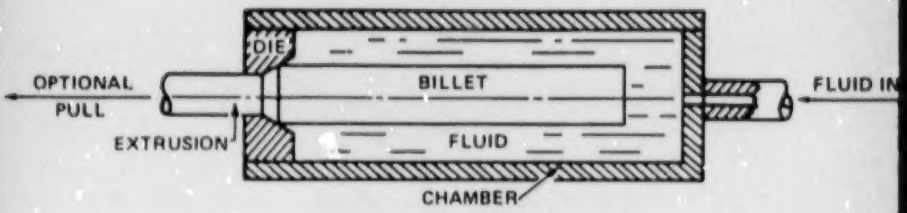

Figure 1. Example of a Good Figure (Courtesy of the Society of Manufacturing Engineers)

If you conducted a survey, this subsection might be titled "Survey Design" rather than "Project Resources". You might describe the questionnaire you designed and provide a copy in an appendix. You might discuss the rationale behind the type or format of questions asked. You might describe the group surveyed in terms of such things as age range, educational background, occupation, or geographical location.

This subsection, together with the description of the procedure you followed in your research, must give the readers sufficient information to judge the validity of your results and your conclusions. The readers must also be able, should they wish to do so, to duplicate your equipment and to repeat your procedure on the basis of the information you provide.

Project Procedure

In this subsection you should describe the procedure you followed. If you found it impossible to follow the plan presented in your proposal, you must explain how and why you deviated and discuss the possible impacts on project results.

If your investigation consisted of a number of steps, you should give the readers an overview of the discussion to follow by listing the steps. For example, you might provide a list something like this:

Step 1 - Design and Construction of Apparatus

Step 2 - Preparation of Samples

Step 3 - Exposure of Samples

Step 4 - Collection and Organization of Data

Step 5 - Data Analysis.

Then you would discuss the steps in order, as illustrated here.

Step 1 Design and Construction of Apparatus

You might describe, for example, the basis on which significant design decisions were made, such as cost or limited space available. You might list the components you were able to purchase ("off-the-shelf" equipment) and to use without modification. You might describe preliminary tests you had to make to ensure that the equipment was calibrated or operating properly. You might describe special provisions you made to ensure constant temperatures over a holiday period.

Step 2 Preparation of Samples

You might describe how you screened samples to ensure purity, desired color, correct weight, appropriate age, or other characteristics required to ensure consistency or compatibility. You might describe how you mounted samples, mixed them with a diluent, or otherwise prepared them for your experiment.

Step 3 Exposure of Samples

You could discuss exposure conditions, control problems, unanticipated reactions and the way you dealt with them, or other significant facts or events. For example, if you found that some of the samples had been contaminated, you should explain what you did with them, and why, and how you protected other samples from similar contamination.

Step 4 Collection and Organization of Data

It might be important to describe how you gathered and organized data. Your methods could affect the accuracy of your results. You might discuss the kind of data you gathered, how often you recorded information, your method of keeping records, any subjective judgments required, and how you handled ambiguous data.

This discussion might include tables, graphs, or other readers' aids. Table 1 shows a typical presentation of data. Summary tables of data might be, with all the supporting raw data compiled during the project being relegated to an appendix.

Table 1 - Example of a Good Table*

Table 1 - PRESSURE BURST TEST AT 1000°C

Sample Number	Internal Pressure (psia)	Rupture[a] (hr)	Remarks
6-11	8000.4	23.8	Burst at bottom weld
7-12	7998.1	24.1	Burst at cap weld
8-10	6495.8	90.5	Burst at cap weld
9-14	6502.1	92.1	Burst at bottom weld

[a]Measured from time sample was at test temperature and pressure.

* Reprinted with permission from Publication Guide-Lines, Monsanto Research Corporation, Mound Facility, Miamisburg, OH (July 1979).

Step 5 Data Analysis

This discussion should present your methods of data analysis. Did you use a statistical approach? Were detailed calculations needed? It might be necessary to discuss an unanticipated scatter of data points along a portion of a curve in one of your illustrations. All significant data must be presented and interpreted.

If possible, compare your experimental results with experimental results obtained by other investigators or with calculated or theoretical results.

ASSESSMENT OF PROJECT RESULTS

This section must support the Results, Conclusions, Recommendations section or sections. It must also support the Future Research Needs section if you choose to include such an elaboration on your recommendations. This section is also

directly related to your project objectives as stated in your proposal. No aspect of these objectives can be ignored.

FUTURE RESEARCH NEEDS

This section is not always included. However, if you have learned something during your investigation that reveals the desirability of additional investigations, or the need for better controlled experiments, you might want to outline in some detail what you think should be done in the future. This section might become the basis of a follow-on proposal for another research project during the next school year.

PROJECT MANAGEMENT

Before you started your investigation, you probably made a commitment in your proposal or research plan to The Ohio Academy of Science to work to reach a specific goal within a certain budget and schedule. You probably also agreed to submit a specific product ("deliverable") at the end of your project, such as a written report and possibly other documentation (photographs, a computer printout, etc.).

In other words, you agreed to manage project resources (funds and time) efficiently, to adhere to the objectives agreed upon, and to communicate your results. This section should describe how you fulfilled (or why you were unable to fulfill) your management commitments.

Financial Management

An important part of your report is your accounting for the funds spent. The financial information in your report might be presented primarily in a table. The table might include, for example, a comparison of your projected and actual costs for equipment and "consumables". You should explain any differences and tell how you have dealt with them. For example, if you found a large item of equipment on sale for only half of what you estimated it would cost, you might state that a check for the difference has been sent to The Ohio Academy of Science in a separate envelope to repay a portion of the grant you received.

Schedule Management

Any significant deviations from the agreed-upon schedule should also be explained and the implications discussed. For example, if replies to your questionnaire were slow in coming in, you might not have been able to include the last 25 received in your calculations.

Submission of Deliverables

You should refer to the submission of any deliverables promised in addition to the report itself. For example, you might have agreed to send some rock samples to the local science museum. Failure to deliver on time, or to meet any other type of obligation on schedule, should be discussed.

ACKNOWLEDGMENTS

It is courteous, and sometimes obligatory, to acknowledge special assistance or guidance provided by others, such as teachers. However, permission to acknowledge such help should be obtained in advance. Some persons might not appreciate the use of their names if this could be interpreted as an endorsement of the work or as agreement with the conclusions or recommendations. Often acknowledgments are made in a separate section at the beginning of a report or as part of another section, such as the introduction.

If permission to use such things as photographs or other illustrations was granted, this should be acknowledged specifically. Figure 1 and Table 1 in this example show two possible ways of making such acknowledgments.

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EXAMPLE TECHNICAL PAPER

and

JOURNAL EDITOR'S INSTRUCTIONS

UTILIZATION OF SPACE BY CAPTIVE GROUPS OF LOWLAND GORILLAS (*GORILLA G. GORILLA*)[1]

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ABSTRACT. Juvenile lowland gorillas caged together in 2 groups at Cincinnati Zoo displayed habitual use of particular cage sections. Dominant larger gorillas limited their space use more than did smaller gorillas.

OHIO J. SCI. 82(1): 27, 1982

INTRODUCTION

Territoriality and dominance behavior are 2 methods by which animals control resource allocation among conspecifics. Many studies of vertebrates show that a defense of given areas and a dominance hierarchy exist as 2 points on a continuum of behavior that is dependent upon density (Wilson 1975). Generally, a population that exhibits territories at lower densities will shift toward dominance behavior at higher densities. The banded knife-fish, *Gymnotus carapo*, is the only vertebrate known to display the reverse behavioral scaling: from dominance orders at lower densities toward territories at higher densities (Black-Cleworth 1970). At low densities in an aquarium, the dominant knife-fish tour the tank with few challenges from lower-ranking knife fish. When challenges increase due to higher populations in the aquarium, the higher-ranking fish spend more time in their preferred areas, thereby decreasing aggressive interactions with subordinates.

Several investigations of mammals have determined that increased densities in confined populations result in a shift from space-associated behavior toward dominance behavior (Wilson 1975). On the other hand, dominance behavior is normal in a group-living mammal such as the gorilla (Schaller 1963). The present study

[1]Manuscript received 7 October 1980 and in revised form 29 May 1981 (#80-53).

was designed to determine if gorillas, like banded knife-fish, exhibit habitual use of particular spatial locations when confined in an enclosure. The subjects of the study were juvenile lowland gorillas housed at Cincinnati Zoo.

METHODS AND MATERIALS

Cincinnati Zoo recorded 4 successful births of lowland gorillas (*Gorilla g. gorilla*) in 1970 and 1971. The birth dates were 25 January 1970 for male Sam, 11 January 1970 for female Samantha, 12 July 1971 for male Ramses, and 12 September 1971 for female Kamari. The 4 animals were first housed together during 1974. They were observed from 21 December 1974 through 20 March 1975 (period 1), and from 1 October through 28 October 1975 (period 2).

Three female gorillas were born at the zoo in 1973 and 1974. The birth dates were 1 January 1973 for Amani, 15 April 1974 for Tara, and 21 August 1974 for Mata Hari. The animals were caged together during 1977. They were observed from 15 November through 10 December 1977 (period 3).

The gorillas' cage consisted of a public-viewing compartment, approximately 3.9 × 3.3 × 4.6 m, and a retreat compartment, approximately 1.5 × 1.2 × 1.2 m. By using the cage's bars and wall tiles as visual cues, the public-viewing compartment was divided into 36 units, each approximately 1.5 × 1.1 × 1.1 m. Seven of the units could not be occupied due to their lack of bars, chains or platforms for supporting the gorillas. The remaining 29 units and the retreat compartment were each identified by a site number for observation purposes (fig. 1). Sites 1-9 were in the south section of the cage, 10-18 were in the middle, and 19-30 were in the north. Sites 1-5, 10-12, and 19-22 were in the west section, 6-7, 13-15, and 23-26 were in the center, 8-9, 16-18, and 27-30 were in the east.

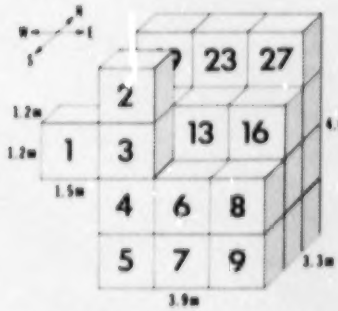

FIGURE 1. Diagram of cage, with retreat compartment (site 1) and public-viewing compartment (sites 2-30).

Data were collected during 1218 minutes of period 1, 494 minutes of period 2, and 1727 minutes of period 3. A time sampling technique was employed, wherein records were made of the gorillas' locations as the second hand passed the minute mark. All observations were made between 9:00 and 16:00 EST.

The "spread of participation index," a numerical measure of spatial behavior (Dickens 1955, Sundstrom and Altman 1974), was calculated for each subject for each of the observation periods 1-3. The index is calculated by the formula:

$$S = \frac{M(n_b - n_a) + (F_a - F_b)}{2(N - M)}$$

where

N = total number of observations of the subject,

M = mean frequency of observations in all of the cage sites = $\frac{N}{\text{number of sites}}$,

n_b = number of sites with frequencies less than M,

n_a = number of sites with frequencies greater than M,

F_a = total number of observations in sites with frequencies greater than M,

F_b = total number of observations in sites with frequencies less than M.

The spread of participation index ranges from zero to an upper limit of one. Low scores indicate equal usage of many sites. The higher the score, the greater the tendency of a subject to use just a few sites. An index of 1.0 indicates a subject's use of a single site.

RESULTS

Spread of participation index values are listed in table 1. During the 2 periods when Sam, Samantha, Ramses and Kamari were observed, the mean index values were 0.547 and 0.565. The slight rise in the index during period 2 suggests that the subjects made more frequent use of particular sites than during period 1. However, a paired *t*-test indicated that the period 2 increase was not significant.

Sam, Samantha, Ramses and Kamari each spent more time in the west section of

TABLE 1
Spread of participation index values.

Period:	1	2		3
Samantha	0.676	0.654	Amani	0.626
Sam	0.559	0.586	Tara	0.617
Kamari	0.489	0.534	Mata Hari	0.514
Ramses	0.455	0.477		

the cage than in the east or center sections. In a north-south orientation, however, Kamari was the most common resident of the south section, Ramses mostly occupied the north section, and Sam and Samantha spent most of their time in the middle section (fig. 2). During period 3, Amani, Tara and Mata Hari spent more time in the north section than in the south or middle sections. From an east-west aspect, however, the most common resident in the west section was Amani, in the east was Tara, and in the center was Mata Hari (fig. 3).

DISCUSSION

The gorillas displayed habitual use of particular sections of their enclosure. Of 7 subjects, 2 exhibited the same spatial preferences. Sam and Samantha spent approximately ½ of their time in the middle section, ⅓ in the south, and ⅙ in the north (fig. 2). The two gorillas were 8 days apart in age, and had been raised together since their births (Lotshaw 1971). The spatial affinity of Sam and Samantha is consistent with field observations that gorillas familiar with each other from immaturity spend more time together than do gorillas that did not know each other in immaturity (Harcourt 1979).

The subjects' frequent use of certain sites was quantified by their spread of participation index values (table 1). The values, all between 0.4 and 0.7, indicate that there was an uneven distribution of locational data for each of the gorillas. The index values also disclose a positive relationship between body size and the degree to which a subject limited his space use. Sam and Samantha had higher index values than did the smaller Ramses and Kamari during both periods 1 and 2. At the end of period 2, Sam and Samantha each weighed 45 kg, and Ramses and Kamari each weighed 29 kg. Amani had a higher index value than did Tara or Mata Hari during period 3. At the end of period 3, Amani weighed 45 kg, and Tara and Mata Hari each weighed 32 kg.

Within groups of juvenile gorillas, body size is positively correlated with status in the dominance hierarchy (Schaller 1963, Freeman and Alcock 1973). On the basis of interactions shown in response to food, Sam and Samantha were dominant over Ramses and Kamari, and Amani was dominant over Tara and Mata Hari.

Fischer and Nadler (1977, 1978) have pointed out that spacing in a wild gorilla group is facilitated by dominance behavior. A less dominant member avoids the space around a dominant animal. Size dominance might also be related to spacing in

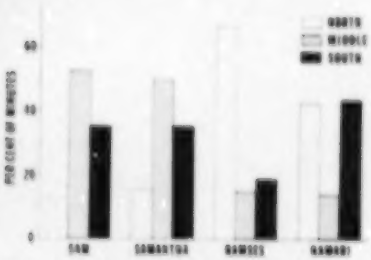

FIGURE 2. Number of minute intervals during which a gorilla was located in north, middle and south cage sections, expressed as a percentage of the number of minute intervals for which the gorilla was watched.

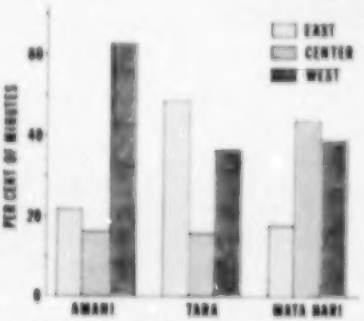

FIGURE 3. Number of minute intervals during which a gorilla was located in east, center and west cage sections, expressed as a percentage of the number of minute intervals for which the gorilla was watched.

caged groups of gorillas. As in a free-ranging troop, a larger dominant gorilla in a confined group may occupy a space that he prefers, leaving the subordinates to distribute themselves throughout the remainder of the cage. Although the dominant animal is able to roam the entire cage, there is a positive relationship between dominance rank and frequent use of certain areas. Consistent with this idea, a study of male prison inmates found that dominant group members were most mobile and also claimed the most desirable places (Austin and Bates 1974). In other confined human groups, dominant members most frequently used the preferable areas in a rehabilitation center cottage (Sundstrom and Altman 1974) and in summer camp cabins (Blood and Livant 1957, Savin-Williams 1977).

In restricted groups of banded knifefish, dominant individuals toured their entire enclosure, but preferred certain areas (Black-Cleworth 1970). Likewise, gorillas in the present study displayed habitual use of particular sections of their enclosure. The dominant larger gorillas limited their space use more than did the smaller gorillas.

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PREPARATION OF MANUSCRIPTS FOR PUBLICATION IN THE OHIO JOURNAL OF SCIENCE

The following suggestions are presented in order to minimize revisions and editorial corrections. Uniformity of style and format necessitates attention to detail by authors.

STYLE. Recent issues of the JOURNAL should be examined so that authors become familiar with its general style. *Three copies of the manuscript should be submitted* typewritten on 8.5 x 11 inch paper with wide margins and **double-spacing throughout**. Manuscripts submitted to the JOURNAL should be assembled in the following manner: title, author's name and address; abstract (unless a brief note); body of the paper (sequence of introduction, methods and materials, results, and discussion); acknowledgements (if applicable); literature cited; tables (if applicable); figure legends; and figures (if applicable). Manuscripts not in this format will be returned. In addition, please indicate an appropriate running head for your paper, consisting of no more than 35 letters and spaces combined.) Do not submit a title or cover page. Page one should include title, author(s), authors address(es) and an abstract. The only words that should be underlined are scientific names. Use arabic numbers instead of spelling out numbers in most cases except the number one and numbers beginning a sentence. Use active voice in most cases. Pages should be numbered consecutively. Extensive quotations in the text should be typed with slightly wider margins. Acceptable symbols should be used for units of measurements, *e.g.*, see Style *Manual For Biological Journals*, compiled by the Conference of Biological Editors of the American Institute of Biological Sciences, 2000 P Street, N. W. Washington, D. C. 20036. (CBE Style Manual).

Title is to be typed in capital letters. Scientific names of organisms in the title should be underlined. The author's name should be typed in capital letters below the title. The address of the department, institution, city and state that are to be credited with supporting the author and his work should be typed (caps and lower case) below the author's name. If more than one institution is to be credited, the names should appear in the order corresponding with the authors' names.

TABLES. Tables are to be typed, double-spaced, on separate sheets of paper, one table to a page, numbered consecutively, and placed in a group at the end of the manuscript. Keep the number of tables at a minimum; numerous small tables especially should be avoided. When the headings for a number of tables are similar, an attempt should be made to combine the tabular data. Use a double horizontal line immediately below the title of the table and a single horizontal line below the column headings and at the bottom of the table. *Do not use horizontal lines in the interior of the table and use no vertical lines.* Tables should be planned and prepared with proper spacing so that such lines are unnecessary. Footnotes to tabular data should be noted by asterisks, daggers, or other signs to avoid confusion with numerals in the table or elsewhere. The general style desired in tables can be seen by examining recent issues of the JOURNAL.

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Make the size and proportions of each group of illustrations suitable for reduction to the width and length of the page ($3\frac{1}{4} \times 7\frac{3}{4}$ inches). Care should be taken to insure that a figure does not occupy more space than necessary. Excessive white space should be eliminated. Line drawings for reproduction are often made too large. As a general rule the dimensions should be no greater than 8 x 10 inches. If carefully drawn, figures need be no more than $33\frac{1}{3}\%$ larger than the size desired in print. Special care should be taken to insure that all lettering is large enough to be read after reduction. A graphic scale should be drawn on each figure to automatically indicate the size of the original regardless of reduction. Original drawings or single weight glossy photographs should be submitted for making engravings. In addition to the original illustration, 2 photographic or xerox type copies of each figure must accompany the manuscript to avoid delay in review.

Captions for figures should be typed in order, double-spaced, on a separate page with the heading FIGURE LEGENDS. Figures are referred to in the text as figure 1 or (fig. 1). The legend should not be placed on the figure that goes to the engraver. Each figure must have a complete legend even though the material is described in the text.

FOOTNOTES. Citations in the text should not be inserted as footnotes but should be included in the LITERATURE CITED. Text footnotes are to be avoided except for: a footnote to the title stating when the manuscript was submitted and revised, acknowledgement of financial support for the article, or departmental or institutional publication numbers. A footnote to the author's name may be used to indicate present address. All other material or comments must be incorporated into the text. *ACKNOWLEDGMENTS* appear in the regular text as a paragraph at the end of the paper. Footnotes to tables are permissible and are encouraged so that the reader can understand the table without reference to the text.

LITERATURE CITED. Reference to scientific literature should be arranged alphabetically by author's last name, and typed, double-spaced, on a separate page at the end of the text. Literature Cited references should follow the Chemical Abstracts or CBE Style Manual form for abbreviations. Examine recent issues of the JOURNAL for details of the form. Use minimal punctuation and no underlines. References are indicated in the text as Patterson (1960) or (Patterson 1960). In the case of more than 2 authors, ——— *et al.* may be used in the text, but all coauthors must be listed in order in the Literature Cited section.

ABSTRACTS. The abstract should be a meaningful summary of the significant facts contained in the paper. It should be sufficient within itself, presenting the main conclusions of the paper and any new methods or procedures critical to the results presented in the paper. It should be brief (not over 250 words) but complete sentences should be used to promote comprehension and clarity. Words such as "is presented," "is explained," or "is discussed" should be avoided. Author abstracts from the JOURNAL appear in the major abstracting journals of the world and may be the only contact that other scientists have with your work.

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